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(54) **REDUCED TORQUE GATE VALVE WITH ROLLER SCREW**

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(52) **U.S. Cl.** **251/327**; 251/267
(58) **Field of Search** 251/264, 266, 251/267, 268, 326, 327, 328; 74/424.71; 384/28

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(57) **ABSTRACT**

A gate valve is disclosed which comprises a valve body which includes a flow bore that extends completely therethrough and a gate cavity that extends partially therethrough and intersects the flow bore, a bonnet which is connected to the valve body over the gate cavity, a gate which is disposed in the gate cavity across the flow bore and includes a transverse opening that extends completely therethrough, a valve stem which includes a first portion that is connected to the gate and a second portion that extends through the gate cavity, a handwheel, and a roller screw assembly which is connected between the handwheel and the second portion of the valve stem and which converts rotation of the handwheel into translation of the valve stem. In this manner, translation of the valve stem raises or lowers the gate to bring the opening into or out of alignment with the flow bore to either open or close the gate valve, respectively.

15 Claims, 3 Drawing Sheets

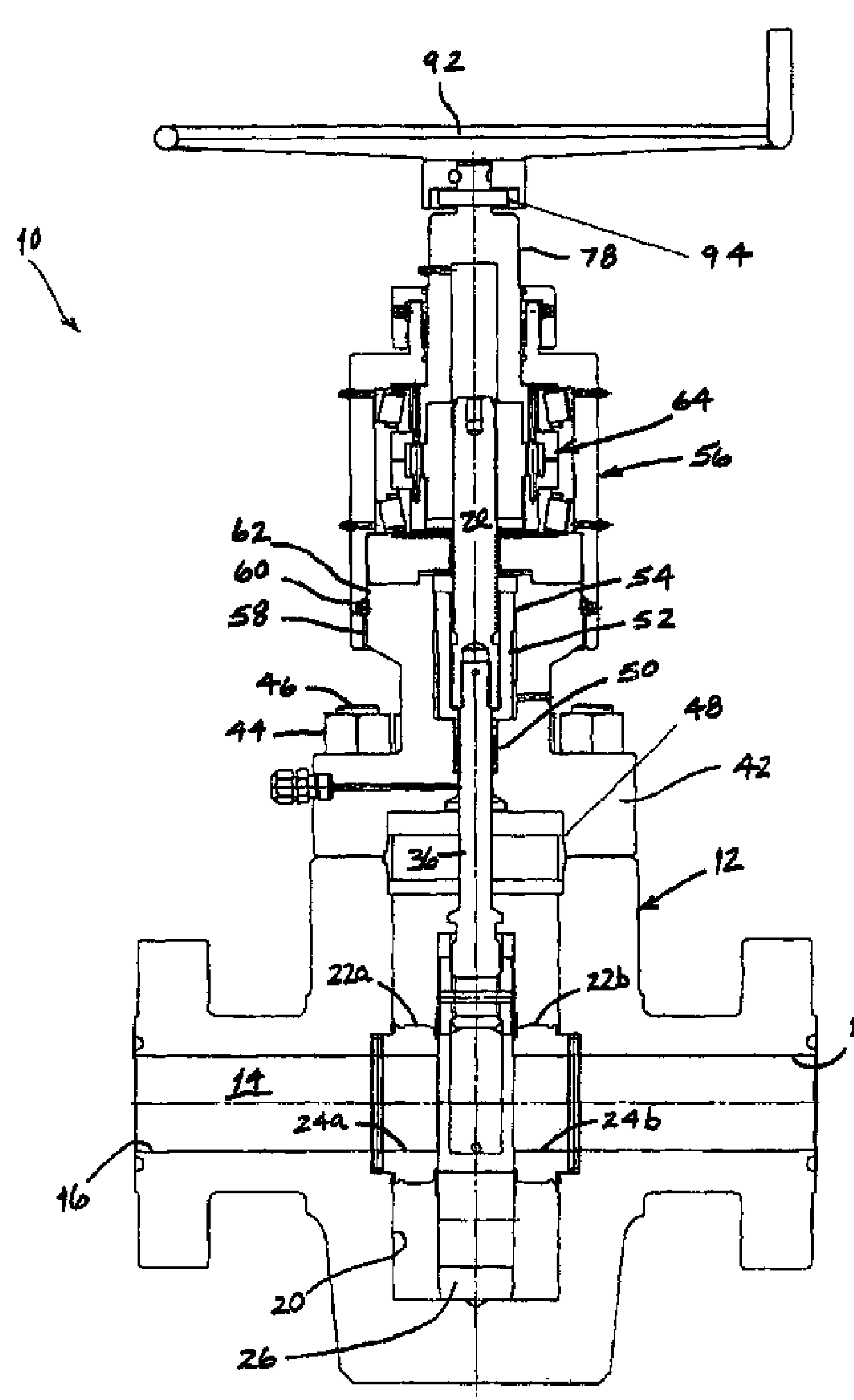
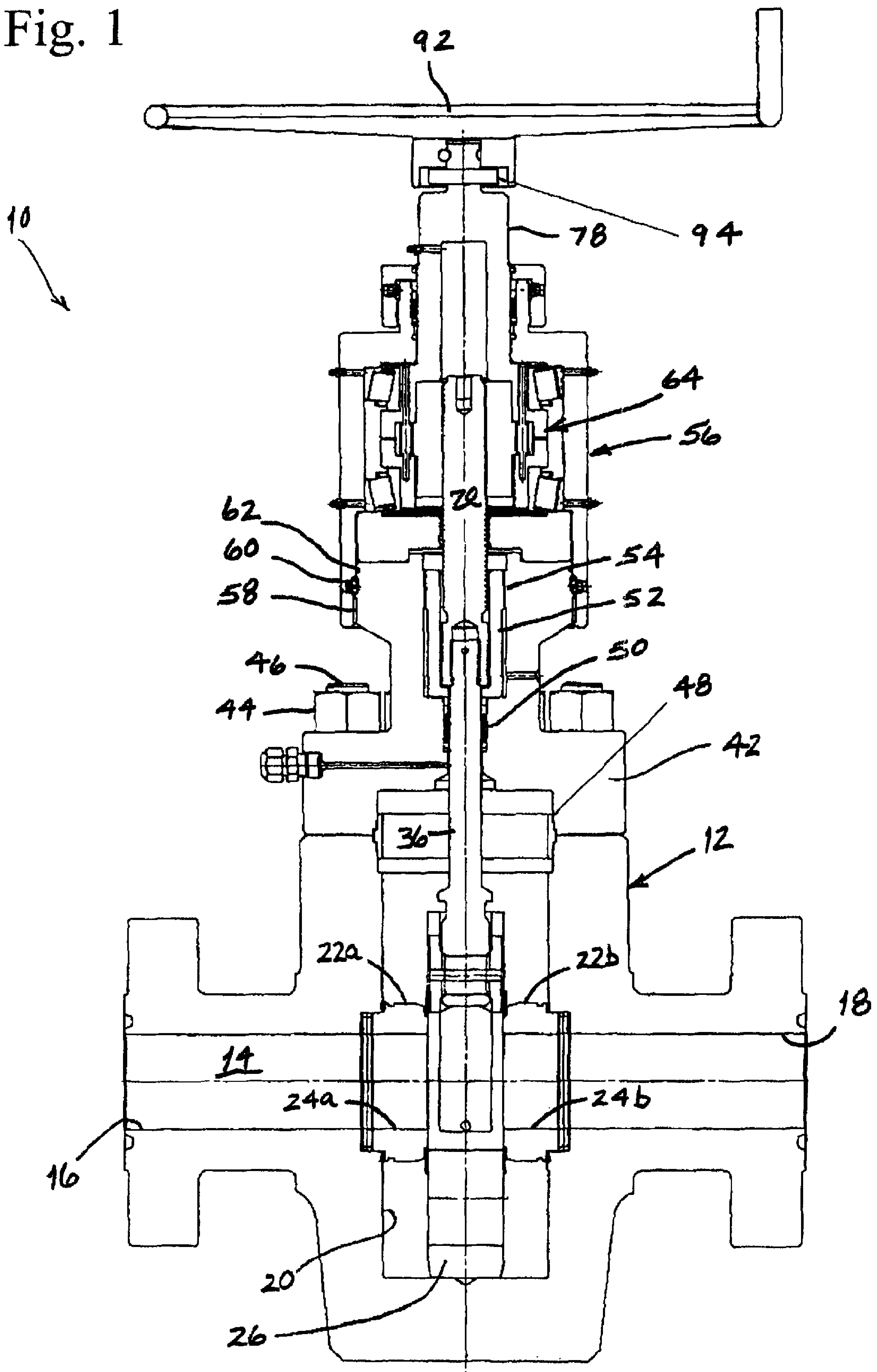


Fig. 1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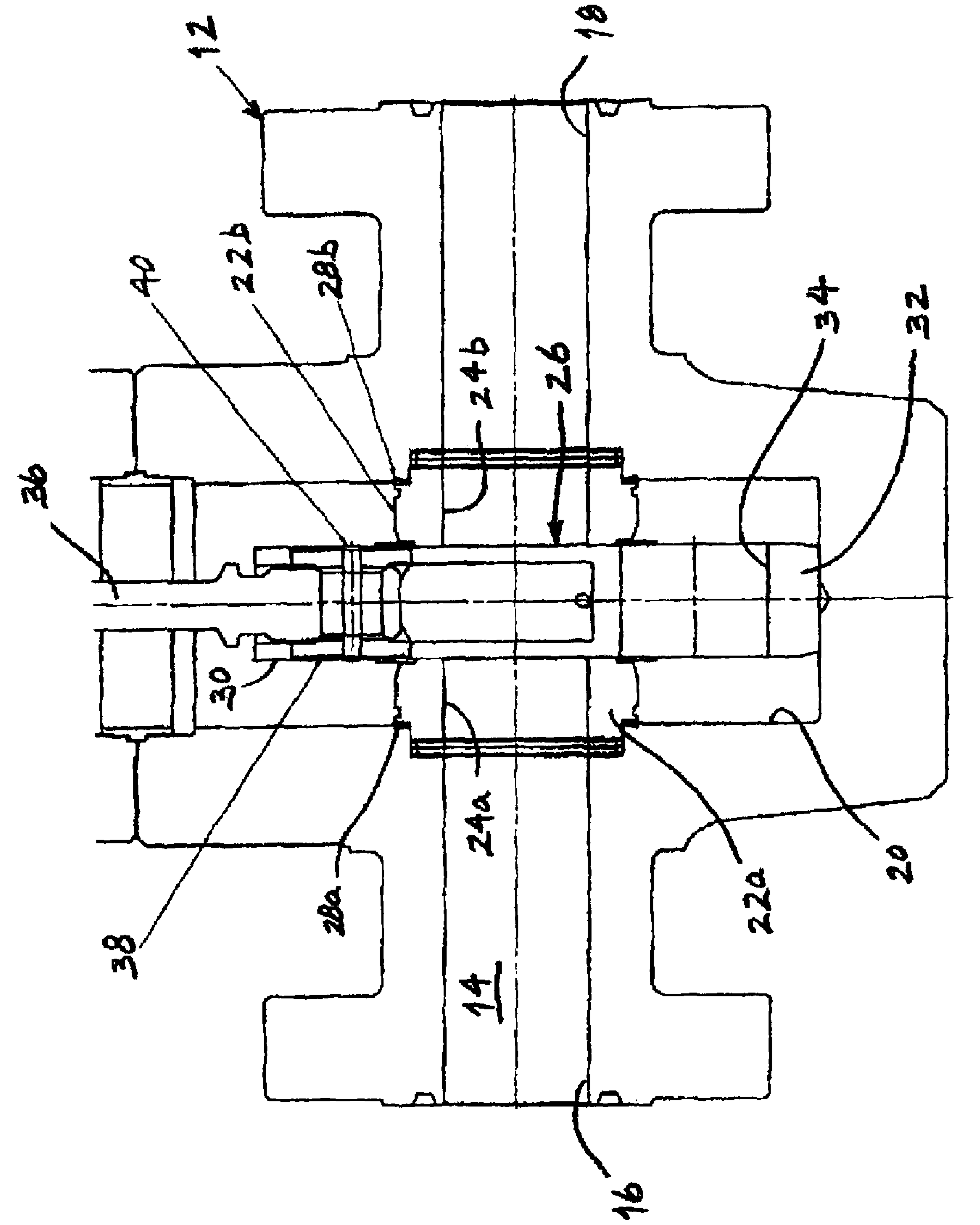

Fig. 2

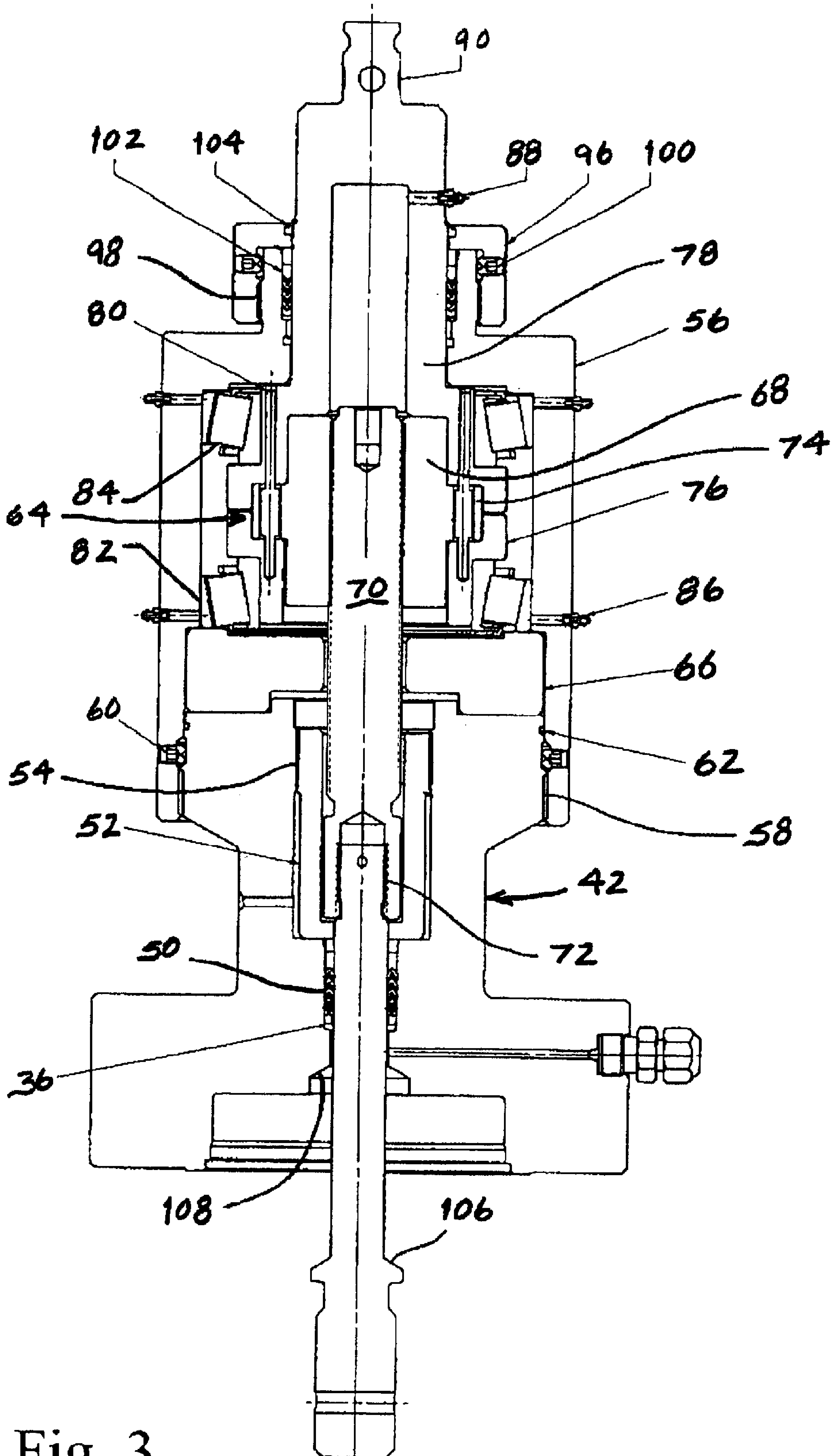
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Fig. 3

REDUCED TORQUE GATE VALVE WITH ROLLER SCREW

This application is based on U.S. Provisional Patent Application No. 60/314,985, which was filed on Aug. 24, 2001.

BACKGROUND OF THE INVENTION

The present invention is directed to a gate valve. More particularly, the invention is directed to a manually actuated, rising stem gate valve which includes a roller screw assembly to efficiently convert rotation of the handwheel into translation of the valve stem.

Gate valves are used in a variety of industries to control the flow of fluids. In particular, gate valves are used extensively in the oil and gas industry to control the flow of produced fluids at various stages of production. Most gate valves used in this industry comprise a valve body having a longitudinal flow bore and a transverse gate cavity that intersects the flow bore. A gate having a gate opening extending transversely therethrough is disposed in the gate cavity. A stem is provided for moving the gate between an open position, in which the gate opening is aligned with the flow bore, and a closed position, in which the gate opening is offset from the flow bore. The gate is usually positioned between a pair of seats, each of which seals against the gate under pressure to prevent fluid from passing through the flow bore when the gate is in the closed position.

The gate cavity is normally covered by a bonnet having an axial through bore. The stem passes through the through bore and is sealed to the bonnet by a stem packing to contain the fluid pressure within the gate cavity. Many gate valves are also provided with a backseat mechanism, that is, cooperating sealing surfaces on the stem and the bonnet which are located below the stem packing. Often a desire exists to perform maintenance or repair on the gate valve, such as replacing the stem packing, without removing the gate valve from the conduit system to which it is connected. In such instances, the stem is moved upwardly until the backseat sealing surfaces on the stem and the bonnet engage and form a metal-to-metal seal. This backseating procedure thus isolates the stem from the gate cavity and allows the desired maintenance to be performed without having to remove the gate valve from the conduit system. For safety reasons, the pressure in the gate cavity is bled down to ambient pressure before any maintenance is performed. In addition, any residual pressure between the stem packing and the backseat is usually bled off through a bleeder plug provided in the bonnet.

Gate valves are provided with means for manipulating the stem to raise and lower of the gate. In this respect, gate valves may be divided into two groups: (a) rising stem gate valves and (b) non-rising stem gate valves. In a non-rising (or rotating) stem gate valve, the stem is threadedly connected to the gate such that rotation of the stem causes the gate to move up and down. An actuation mechanism is provided for selectively rotating the stem clockwise or counterclockwise in order to open or close the gate valve. On this type of gate valve, the backseat is set by driving the gate down until it bottoms out on the valve body, and then allowing the stem to move upward until it backseats against the bonnet. Such valves may be automatically or remotely actuated, such as by an electric motor. Alternatively, these gate valves may be manually actuated, such as by a handwheel adapted to rotate the stem directly. An example of such a manual gate valve is shown in U.S. Pat. No. 5,762,320 to Williams et al.

In a rising stem gate valve, the stem is attached to the gate in a manner which prevents axial movement of the stem relative to the gate. A mechanism is then provided for selectively driving the stem up and down in order to open and close the valve. On this type of gate valve, the backseat is set by moving the stem and the gate upwards until the stem backseats against the bonnet. Such valves may be automatically or remotely actuated, such as by a hydraulic cylinder. Alternatively, these valves may be manually actuated by providing a transmission means to convert the rotational motion of a handwheel into axial motion of the stem.

One such transmission means is a direct threaded connection between the handwheel and the stem. Unfortunately, for many large or high pressure valves which require large actuating forces, this method requires more torque to be applied to the handwheel than is practical to exert by hand. When the valve is closed, the entire upstream side of the gate is exposed to the full working pressure of the fluid while a portion of the downstream side of the gate is often at ambient pressure. This pressure differential results in very high forces which push the gate against the downstream seat. This engagement between the gate and the downstream seat in turn creates large gate-to-seat drag forces which must be overcome when gate is moved from the closed position to the open position. Another force which must be overcome is the drag which the stem packing exerts on the stem.

Rising stem gate valves can be further divided into two types: (a) balanced stem gate valves and (b) un-balanced stem gate valves. In a balanced stem gate valve, a second stem is attached to the gate at the end opposite the first stem. An example of this type of gate valve is shown in U.S. Pat. No. 4,230,299 to Pierce, Jr. It will be appreciated that when pressurized fluid is present in the gate cavity, a force is exerted on each stem which is equal to the product of the pressure and the cross-sectional area of the stem where it passes through the stem packing. In a balanced stem gate valve, the forces acting on the two stems will cancel each other out, resulting in substantially zero (or a balanced) net force to overcome when moving the gate. The disadvantages of balanced stem gate valves include increased cost and complexity and the creation of an additional potential leak path between the second stem and its corresponding stem packing.

An example of an unbalanced stem gate valve is disclosed in U.S. Pat. No. 4,569,503 to Karr, Jr. Although in this type of gate valve the unbalanced stem forces must be overcome when moving the gate, it will be appreciated that this design is simpler than the balanced stem gate valve. In the valve shown in Karr, Jr., the gate opening is disposed in the upper part of the gate, such that the valve is open when the gate is in its lowered position and closed when the gate is in its raised position. The disadvantage of this configuration is that when the valve is moved from the closed position to the open position, both the unbalanced stem force and the maximum gate-to-seat drag forces must be overcome simultaneously.

In order to overcome these combined forces and still maintain the required handwheel torque at an acceptable level, a transmission means which provides a substantial mechanical advantage must usually be utilized. Karr, Jr. provides a ball screw device for raising and lowering the stem. Other valves utilize bevel or worm gear reduction boxes. One disadvantage of these devices is that, in order to sufficiently reduce the required torque on the handwheel, the gear ratio must be very high. Consequently, a large number of turns is required to open or close the valve. Moreover, since the rate at which an operator can turn the handwheel is limited, the gate necessarily traverses very slowly from one position to the other.

This relatively slow traverse is especially troublesome when moving the gate from the closed position to the open position. As soon as the gate opening intersects the flow bore in the downstream seat, the gate-to-seat seal is broken and a high velocity jet of fluid is forced through the intersection area. In many cases, the fluid may contain abrasive particles which tend to erode the valve components during high velocity flow. The longer the intersection area remains small, the longer it takes for pressure to equalize on the opposites sides of the gate. Thus, the slower the gate moves to the open position, the greater the amount of erosion.

A further disadvantage of the gate valves shown in the Williams et al., Pierce, Jr. and Karr, Jr. patents is that these valves must be in the closed position in order to backseat the stem against the bonnet. Consequently, multiple actuations of the valve are required to ensure that both the gate cavity and the bonnet are at ambient pressure. Typically, the valve must first be actuated to the open position in order to bleed down the system pressure on both sides of the valve. Then the valve must be actuated to the closed position in order to backseat the stem against the bonnet.

SUMMARY OF THE INVENTION

In accordance with the present invention, these and other disadvantages in the prior art are overcome by providing a gate valve which comprises a valve body which includes a flow bore that extends completely therethrough and a gate cavity that extends partially therethrough and intersects the flow bore, a bonnet which is connected to the valve body over the gate cavity, a gate which is disposed in the gate cavity across the flow bore and includes a transverse opening that extends completely therethrough, a valve stem which includes a first portion that is connected to the gate and a second portion that extends through the gate cavity, a handwheel, and a roller screw assembly which is connected between the handwheel and the second portion of the valve stem and which converts rotation of the handwheel into translation of the valve stem. In this manner, translation of the valve stem raises or lowers the gate to bring the opening into or out of alignment with the flow bore to either open or close the gate valve, respectively.

In comparison to prior art gate valves, the roller screw assembly requires substantially fewer turns of the handwheel in order to raise and lower the gate. Thus, assuming the operator turns the handwheel at a constant rate, the gate in the gate valve of the present invention will rise substantially faster than the gates in prior art gate valves. Consequently, any erosion of the gate which may occur when the opening first intersects the flow bore will be minimized.

These and other objects and advantages of the present invention will be made apparent from the following detailed description, with reference to the accompanying drawings. In the drawings, the same reference numbers are used to denote similar components in the various embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross sectional view of the gate valve of the present invention shown in the closed position;

FIG. **2** is a cross sectional view of the lower portion of the gate valve shown in FIG. **1**; and

FIG. **3** is a cross sectional view of the upper portion of the gate valve shown in FIG. **1**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. **1**, the gate valve of the present invention, which is indicated generally by reference number **10**, is shown to comprise a valve body **12** which comprises a flow bore **14** that extends longitudinally through the valve body between a first port **16** and a second port **18** and a gate cavity **20** that extends partially through the valve body generally transverse to the flow bore. The gate valve **10** also comprises a pair of seats **22***a*, **22***b*, each of which is positioned at least partially in a corresponding seat pocket that is formed at the intersection of the flow bore **14** and the gate cavity **20**. Each seat **22***a*, **22***b* includes a transverse bore **24***a*, **24***b* that is aligned with the flow bore **14** to thereby define a flow passage through the valve body **12**.

Referring also to FIG. **2**, the gate valve **10** further includes a gate **26** which is slidably disposed between the seats **22***a*, **22***b*, each of which is preferably urged into contact with the gate by a respective Belleville spring **28***a*, **28***b*. The gate **26**, which in an exemplary embodiment of the invention comprises a generally rectangular configuration, includes an upper end **30**, a lower end **32** and a transverse opening **34** that extends completely through the gate proximate the lower end. The gate **26** is secured to a stem **36** by a lift nut **38**, which is mounted in a corresponding recess in the upper end **30** of the gate and threaded to the lower end of the stem. In addition, the stem **36** is secured against rotation relative to the lift nut **38** and the gate **26** by a pin **40**. Thus, any axial translation of the stem **36** will result in a corresponding translation of the gate **26**.

The gate **26** is adapted for reciprocal motion between an upper or open position and a lower or closed position, the latter of which is shown in the Figures. In the open position, the opening **34** in the gate is substantially aligned with the bores **24***a*, **24***b* in the seats **22***a*, **22***b*, and fluid is permitted to flow though the flow bore **14** between the first and second ports **16**, **18**. In the closed position, the opening **34** is offset from the bores **24***a*, **24***b* and the gate **26** thus blocks the flow of fluid through the flow bore **14**. Furthermore, since the gate **26** is secured to the stem **36**, the gate valve **10** may be selectively opened or closed by raising or lowering the stem.

Referring again to FIG. **1**, the gate valve **10** also includes a bonnet **42** which is secured to the valve body **12** over the gate cavity **20** by suitable means, such as a number of bolts **44** and nuts **46**. The bonnet **42** is preferably sealed to the valve body **12** via a bonnet gasket **48**. The stem **36** extends upwardly through the bonnet **42** and is sealed thereto by a stem packing **50**. The stem packing **50** is retained within the bonnet **42** by a packing nut **52**, which is threadedly connected to the bonnet generally at **54**.

Referring also to FIG. **3**, the gate valve **10** further includes a generally cylindrical bonnet cap **56**, which is secured to the bonnet **42** such as by threads **58**. One or more set screws **60** may be provided to prevent relative rotation between the bonnet cap **56** and the bonnet **42**. In addition, an O-ring **62** is ideally positioned between the bonnet cap **56** and the bonnet **42** to provide a seal therebetween.

Referring still to FIG. **3**, the gate valve **10** further comprises a roller screw assembly **64** which is positioned in the bonnet cap **56** immediately above a thrust bushing **66**, which in turn is mounted in the bonnet cap immediately above the bonnet **42**. The roller screw assembly **64** includes a roller screw nut **68** which is rotatably connected to a roller screw shaft **70**. In a preferred embodiment of the invention, the roller screw nut **68** and the roller screw shaft **70** comprise a planetary roller screw assembly such as is shown and described in the “SKF® roller screws” leaflet published by the SKF Group (Catalogue No. 4351/5E, June 1999, France), which is hereby incorporated herein by reference. In this type of roller screw assembly, the roller screw nut **68** comprises a central bore having internal threads, and the roller screw shaft **70** comprises an outer diameter having corresponding external threads. In addition, disposed between and engaging the internal and external threads are a plurality of threaded rollers (not shown in the Figures), which serve to convert the rotational motion of the roller screw nut **68** into axial translation of the roller screw shaft **70**.

The lower end of the roller screw shaft **70** is connected to the upper end of the stem **36** such as by threads **72**. The roller screw shaft **70** and the stem **36** are ideally also pinned together to prevent relative rotation therebetween. Thus, it can be appreciated that the roller screw shaft **70**, the stem **36**, the lift nut **38** and the gate **26** will all translate axially as a unit, but will not rotate relative to each other.

The roller screw nut **68** comprises a radially outwardly extending flange **74** which is disposed between a roller thrust bearing **76** and a roller adapter shaft **78**. In addition, the flange **74** is preferably pinned to the roller thrust bearing **76** and the roller adapter shaft **78** via one or more pins **80** so that the roller screw nut **68**, the roller thrust bearing and the roller adapter shaft will rotate as a unit. This unit is supported on a lower roller bearing **82** which is mounted between the roller thrust bearing **76** and the bonnet cap **56** and which in turn is supported on the thrust bushing **66**. Furthermore, an upper roller bearing **84** is mounted between the roller adapter shaft **78** and the bonnet cap **56**. In a manner well known in the mechanical arts, the roller bearings **82**, **84** serve to guide the roller thrust bearing **76** and the roller adapter shaft **78** as they rotate, while reducing rotational drag on these components. Roller bearings **82**, **84** further serve to transmit axial and radial loads from the roller thrust bearing **76** and the roller adapter shaft **78** to the thrust bushing **66** and the bonnet cap **56**. One or more grease fittings **86** and **88** may be provided on the bonnet cap **56** and the roller adapter shaft **78**, respectively, for providing lubrication to the roller bearings **82**, **84** and the roller screw assembly **64**.

The upper end of the roller adapter shaft **78** extends beyond the bonnet cap **56** and terminates in a handwheel adapter portion **90**. As shown in FIG. **1**, a Handwheel **92** is attached to the adapter portion **90** by suitable means, such as a pin **94**.

Referring again to FIG. **3**, the gate valve **10** also includes a bonnet cap adapter **96**, which is preferably threadedly connected to the bonnet cap **56** generally at **98**. In addition, one or more set screws **100** may be provided to prevent rotation of the bonnet cap adapter **96** relative to the bonnet cap **56**. The bonnet cap adapter **96** serves to retain a packing **102** which is disposed between the roller adapter shaft **78** and an upper portion of the bonnet cap **56**. A wiper ring **104** is ideally positioned between bonnet cap adapter **96** and the roller adapter shaft **78** to prevent contamination of the packing **102**.

A primary purpose of the packing **102** is to impart rotational drag to the roller adapter shaft **78**. Because the gate valve **10** is an unbalanced stem gate valve, fluid pressure in the gate cavity **20** will impart an upward force on the stem **36**. Since the roller screw assembly **64** is somewhat susceptible to backdrive, this upward force could move the gate **26** upwards toward the open position. Therefore, the size, design, material and preload of packing **102** should be selected to provide an optimal amount of drag on the roller adapter shaft **78** to prevent this backdrive.

The normal operation of the gate valve **10** will now be described. In order to open the gate valve **10**, an operator applies a torque to the handwheel **92**. This torque is transmitted to the roller adapter shaft **78** via the pin **94**, and then to the roller screw nut **68** and the roller thrust bearing **76** via the pins **80**. As described above, the roller screw assembly **64** serves to convert the torque on the roller screw nut **68** into an upward axial force on the roller screw shaft **70**. The resulting downward axial reaction force on the roller screw nut **68** is transmitted through the roller thrust bearing **76**, the lower roller bearing **82**, the thrust bushing **66** and the bonnet **42** to the valve body **12**. It should be noted that the roller screw assembly **64** provides an improved mechanical advantage over the ball screw devices utilized in the prior art. Consequently, less applied torque is required at the handwheel **92** in order to actuate the gate valve **10**.

As the handwheel **92** is actuated to open the gate valve **10**, the resulting upward axial force on the roller screw shaft **70** is transmitted through the stem **36**, the pin **40** and the lift nut **38** to the gate **26**. As the torque applied to handwheel **92** is increased, the upward axial force on the gate **26**, the stem **36** and the roller screw shaft **70** increases accordingly. When this upward force is sufficient to overcome the sum of the gate-to-seat drag between the gate **26** and the seats **22***a*, **22***b* and the stem-to-packing drag between the stem **36** and the packing **50**, the gate, the stem and the roller screw shaft **70** will begin to rise towards the open position. At this point, the advantage of using a standard gate **26**, with the gate opening **34** proximate the lower end **32**, will become apparent. In most gate valves, greater force is required to open the valve than to close the valve. This is because in the closed position, the full differential pressure across the gate creates the greatest gate-to-seat drag. By using a standard gate **26** in the gate valve of the present invention, the upward force acting on the unbalanced stem will help to move the gate into the open position.

As the operator continues to apply torque to the handwheel **92**, the handwheel will rotate and the gate **26** will rise. For simplicity sake, let us assume that the high pressure side of the gate valve **10** is to the left of the gate **26** (as viewed in the Figures). Thus, when the gate valve **10** is open, flow will proceed through the flow bore **14** from the first port **16** to the second port **18**. As discussed above, when the upper edge of gate opening **34** reaches the bore **24***b* in the downstream seat **22***b*, a high velocity jet of fluid will be forced through the intersection of the gate opening and the bore. Therefore, it is desirable to raise the gate **26** as quickly as possible in order to minimize any erosion which may be caused by this jet of fluid.

At this point an additional advantage of the roller screw assembly **64** over prior art ball screws will be made apparent. The roller screw assembly **64** requires substantially fewer turns on the handwheel **92** in order to raise the roller screw shaft **70** the distance required to fully open the gate **26**. Thus, assuming the operator turns the handwheel **92** at a constant rate, the gate **26** will rise substantially faster in the gate valve **10** than in prior art gate valves which utilize ball screws. Consequently, erosion of the gate opening **34** and the bore **24***b* of the downstream seat **22***b* will be minimized.

As the gate **26** is raised still further, the gate opening **34** will eventually become substantially aligned with bores **24***a*, **24***b* in the seats **22***a*, **22***b*. In this configuration, the gate valve **10** is fully open and fluid may flow freely through the flow bore **14**. As the gate **26** reaches its fully open position, a back seat surface **106** on the stem **36** will engage a corresponding backseat surface **108** on the bonnet **42** and create a metal-to-metal backseat seal. At this point, an additional advantage to using a standard gate **26** will become apparent. With the gate valve **10** thus actuated to the open position and simultaneously backseated, pressure may be bled off from both sides of the gate **26** and from the bonnet **42** without having to actuate the gate valve a second time. Thus, fewer steps are required to ensure that no gage pressure exists in the gate cavity **20** and the bonnet **42**. Consequently, maintenance and repair functions, such as replacing the stem packing **50**, may be safely performed relatively easily and inexpensively.

When it is desired to close the gate valve **10**, the operator rotates the handwheel **92** in the opposite direction, and the roller screw shaft **70**, the stem **36** and the gate **26** are driven downward toward the closed position. The unbalanced stem force now opposes the motion of the gate **26**. However, this opposing force is offset by the fact that essentially no gate-to-seat drag exists when the gate valve **10** is open since no differential pressure exists across the gate **26**. Moreover, the upward reaction force exerted on the roller screw nut **68** is transmitted through the roller adapter shaft **78**, the upper roller bearing **84**, the bonnet cap **56** and the bonnet **42** to the valve body **12**.

It should be recognized that, while the present invention has been described in relation to the preferred embodiments thereof, those skilled in the art may develop a wide variation of structural and operational details without departing from the principles of the invention. Therefore, the appended claims are to be construed to cover all equivalents falling within the true scope and spirit of the invention.

What is claimed is:

1. A gate valve which comprises:

a valve body which includes a flow bore that extends completely therethrough and a gate cavity that extends partially therethrough and intersects the flow bore;

a bonnet which is connected to the valve body over the gate cavity;

a gate which is disposed in the gate cavity across the flow bore and which includes a transverse opening that extends completely therethrough;

a valve stem which includes a first portion that is connected to the gate and a second portion that extends through the gate cavity;

a handwheel;

a roller screw assembly which is connected between the handwheel and the second portion of the valve stem and which converts rotation of the handwheel into translation of the valve stem;

wherein translation of the valve stem raises or lowers the gate to bring the opening into or out of alignment with the flow bore to either open or close the gate valve, respectively;

wherein the roller screw assembly includes a roller screw nut which is connected to the handwheel and a roller screw shaft which connected to the valve stem and is rotatably received within the roller screw nut;

a roller thrust bearing which is secured to the roller screw nut; and

a roller adapter shaft which includes a lower portion that is secured to the roller screw nut and an upper portion that is connected to the handwheel;

wherein rotation of the handwheel rotates the roller adapter shaft, the roller screw nut and the roller thrust bearing in unison.

2. The gate valve of claim **1**, wherein the roller screw nut includes a radially extending flange which is disposed between the roller thrust bearing and the roller adapter shaft, and the roller screw nut is secured to the roller thrust bearing and the roller adapter shaft through the flange.

3. The gate valve of claim **1**, further comprising:

a bonnet cap which is secured to the bonnet;

wherein the roller screw nut, the roller thrust bearing and the lower portion of the roller adapter shaft are positioned in the bonnet cap.

4. The gate valve of claim **3**, further comprising a lower roller bearing which is positioned between the roller thrust bearing and the bonnet cap.

5. The gate valve of claim **4**, further comprising an upper roller bearing which is positioned between the roller adapter shaft and the bonnet cap.

6. The gate valve of claim **4**, further comprising a thrust bushing which is positioned between the lower roller bearing and the bonnet.

7. The gate valve of claim **3**, further comprising means for exerting rotational drag on the roller adapter shaft.

8. The gate valve of claim **7**, wherein the drag means comprises a packing which is positioned between the roller adapter shaft and the bonnet cap.

9. A gate valve which comprises:

a valve body which includes a flow bore that extends between an inlet port and an outlet port, and a pate cavity that intersects the flow bore;

a gate which is disposed in the gate cavity across the flow bore;

a valve stem which includes a first end that is connected to the gate;

a roller screw assembly which includes a roller screw shaft that is connected to or formed integrally with a second end of the valve stem and a roller screw nut which is rotatably connected to the roller screw shaft; and

an adapter shaft which is connected to the roller screw nut;

wherein rotation of the adapter shaft rotates the roller screw nut and thereby moves the roller screw shaft and the valve stem axially to position the gate across the flow bore;

a bonnet which is connected to the valve body over the gate cavity; and

a first roller bearing which is positioned between the bonnet and the roller screw nut.

10. The gate valve of claim **9**, further comprising a thrust bushing which is positioned between the bonnet and the first roller bearing.

11. The gate valve of claim **9**, further comprising a bonnet cap which is secured to the bonnet over the roller screw nut.

12. The gate valve of claim **11**, wherein the adapter shaft comprises a radial flange which is positioned within the bonnet cap and the gate valve further comprises a second roller bearing which is positioned between the flange and the bonnet cap.

13. The gate valve of claim **12**, further comprising a roller thrust bearing which is positioned between the roller screw nut and the first roller bearing.

14. The gate valve of claim **13**, further comprising means for securing the adapter shaft and the roller thrust bearing to the roller screw nut to prevent relative rotation therebetween.

15. The gate valve of claim **14**, wherein the securing means comprises at least one pin which extends between the adapter shaft, the roller screw nut and the roller thrust bearing.

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